Vascularized Bone Grafts from the Dorsal Wrist for the Treatment of Kienböck Disease

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Abstract

Purpose The objective of this article is to evaluate functional and radiological outcomes of vascularized bone grafts for stage 2 and 3 Kienböck disease. The outcomes of three different donor sites via dorsal approach of the wrist were compared. Pearls and pitfalls in surgical technique were discussed.

Methods There were 28 patients who underwent vascularized bone grafts, including the extensor fourth and fifth compartmental artery graft of distal radius in 8 patients, the first and second supraretinacular intercompartmental artery graft of distal radius in 12 patients, and the second dorsal metacarpal neck graft in 8 patients. Average age was 32 years, and radiological grading according to Lichtman classification was stage 2 in 8 patients, stage 3A in 10 patients, and stage 3B in 10 patients. Temporary pinning fixing the midcarpal joint was conducted for 10 weeks postoperatively.

Results Follow-up periods averaged 70 months. Pain reduced in 27 patients, and visual analog scale for pain of pre- and postoperative level averaged 59 and 18. Range of wrist flexion and extension motion improved from 87 to 117 degrees, and average grip strength improved from 21 kg preoperatively to 33 kg postoperatively. Carpal height ratio had almost no change from 0.52 to 0.53. Fragmentation of necrotic bone healed in 7 of the 14 cases. Comparative analyses of functional and radiological outcomes between three donor sites found no significant difference.

Conclusion Three different vascularized bone grafts from the dorsal wrist and hand area demonstrated favorable and comparable functional outcomes. It was technically important to elevate vascular bundle with surrounding retinaculum or fascia, to include sufficient periosteum, and to insert the vascularized bone as the cortex aligned longitudinally.

Keywords
- vascularized bone
- grafting
- lunate
- osteonecrosis
- Kienböck

Previous literatures described various methods of treatment for Kienböck disease depending on the patient characteristics, the severity of the symptom, and radiological staging.[1–8] Treatment options range from conservative measurements to surgical interventions.[9–12] Several authors advocated a biomechanical approach to reduce load transmission on the necrotic lunate,[13–19] and good clinical results have been reported in joint leveling procedures such as radial shortening or ulnar lengthening[20–22] and in radial or ulnar wedge osteotomy.[23,24]

Hori et al[25] introduced a biological approach of revascularization for necrotic bones based on their experimental results. Since then, there have been several donor sites available for vascularized bone graft in the treatment of

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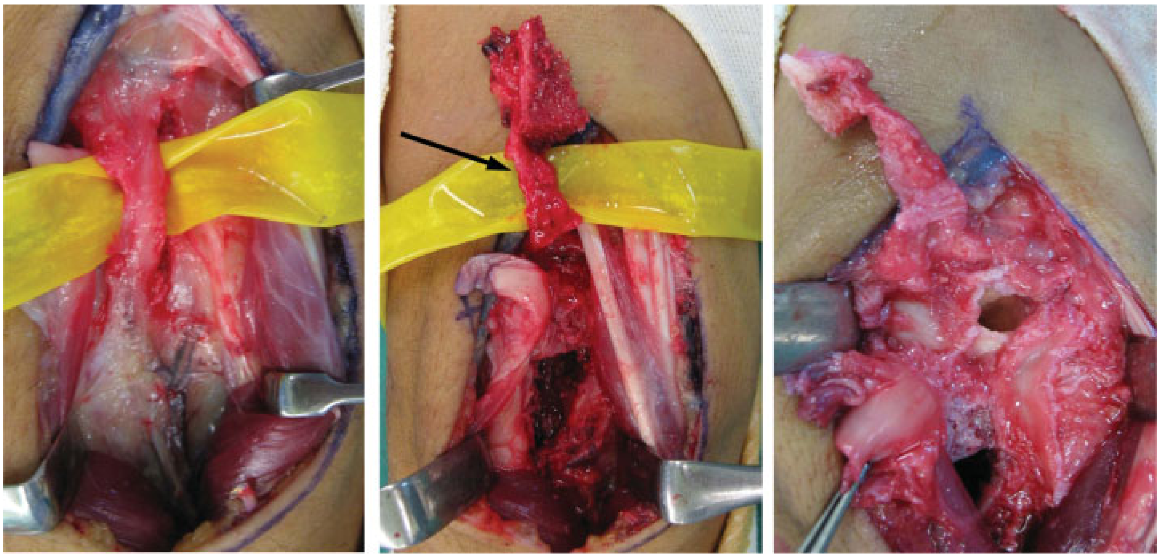

Fig. 1 Vascularized distal radius bone graft transferrable to the lunate based on the extensor fourth and fifth compartmental artery. After identifying the fourth and fifth compartmental arteries, Y-shaped communication of these arteries was ligated at the dorsal interosseous membrane. Vascularized distal radius was harvested based on the fourth compartmental artery (arrow).

Kienböck disease.[26–31] From the dorsal aspect of the wrist, the extensor compartmental vascularized distal radius[32,33] and the vascularized metacarpal base based on the dorsal carpal artery[34,35] can be found. From the palmer aspect, vascularized os pisiform transfer[36,37] and distal radius transfer based on the palmer carpal artery[38,39] are available. In this article, we evaluated functional and radiological outcomes of vascularized bone grafts for stage 2 and 3 Kienböck disease. Three different donor sites via dorsal approach of the wrist were compared. We discussed pearls and pitfalls in surgical technique.

Patients and Methods

From 1996 to 2002, 28 patients with stage 2 and 3 Kienböck disease were treated by vascularized bone graft only at our institution. There were 21 males and 7 females, and average age was 32 years. We used vascularized bone grafts from three different donor sites: the extensor fourth and fifth compartmental distal radius[29,31,32,40] in 8 patients, the first and second intercompartmental distal radius[41,42] in 12 patients, and the second dorsal metacarpal neck[43–45] in 8 patients. Selection of the donor site was according to the surgeon's preference (►**Figs. 1–4**). Radiological grading according to Lichtman classification was stage 2 in 8 patients, stage 3A in 10 patients, and stage 3B in 10 patients. Distribution of dominant hand involvement, symptom duration, and radiological ulnar variance was comparable between the three groups.

We evaluated functional outcomes using a visual analog scale (VAS) for wrist pain, the ratio of range of active flexion and extension motion in the affected wrist compared with the contralateral side (% ROM), % grip strength (% GS) as well

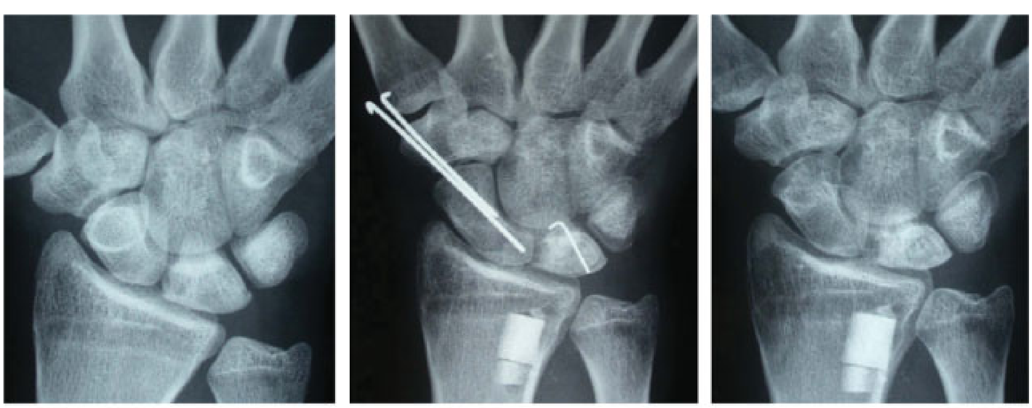

Fig. 2 Sequential X-rays of preoperative, immediately postoperative, and 48 months postoperative posteroanterior views following the extensor fourth and fifth compartmental bone graft.

Arterial Diameter	0.8 mm ± 0.2	(0.2 – 2.0)
Diameter of periosteal br	0.2 mm ± 0.1	(0.1 – 0.7)
Number of periosteal br	2.8 ± 0.6	(2 - 4)

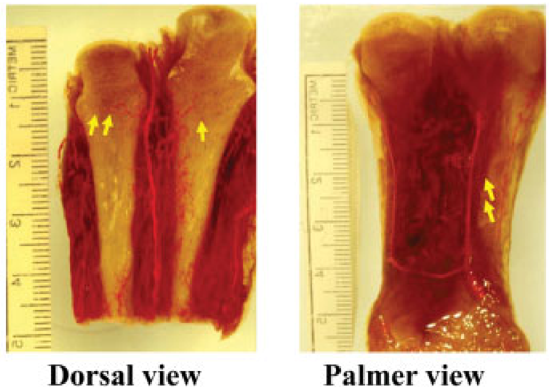

Fig. 3 Anatomical data of the second metacarpal artery and its periosteal branches to the metacarpal neck. Arrows indicate the periosteal branch (Microfil-injected specimens). Arterial diameter of the second metacarpal artery averaged 0.8 mm at the branching site, and diameter of its periosteal branch averaged 0.2 mm.

during the preoperative and the final follow-up periods. Postoperative Disabilities of the Arm, Shoulder and Hand (DASH) score and modified Mayo wrist score were also evaluated. As a radiological outcome, Lichtman staging, fragmentation of the lunate, carpal height ratio (CHR), and radioscaphoid angle (RSA) were measured preoperatively, immediate postoperatively, and during the final follow-up.

Postoperative treatment: Temporary pinning at the midcarpal joint (scaphotrapezial-trapezoid joint or scaphocapitate joint) was used[46,47] to decompress the reconstructed lunate for ~8 to 12 weeks until lunate revascularization. Short arm cast was applied to immobilize the wrist joint for 3 to 6 weeks with an average of 4 weeks. Following removal of the cast, active-assisted range of wrist motion exercise was permitted, and wrist orthosis was applied for ~3 months postoperatively.

Statistical Analysis

Patient characteristics such as age, gender, affected side, symptom duration, and ulnar variance were compared between the three groups.

Pre- and postoperative values of VAS for pain, % ROM, and % GS were compared using paired *t*-test, and each value of the three groups was compared using one-way analysis of variance followed by Tukey post hoc test.

Preoperative values of CHR and RSA were compared with immediate postoperative and final follow-up values using

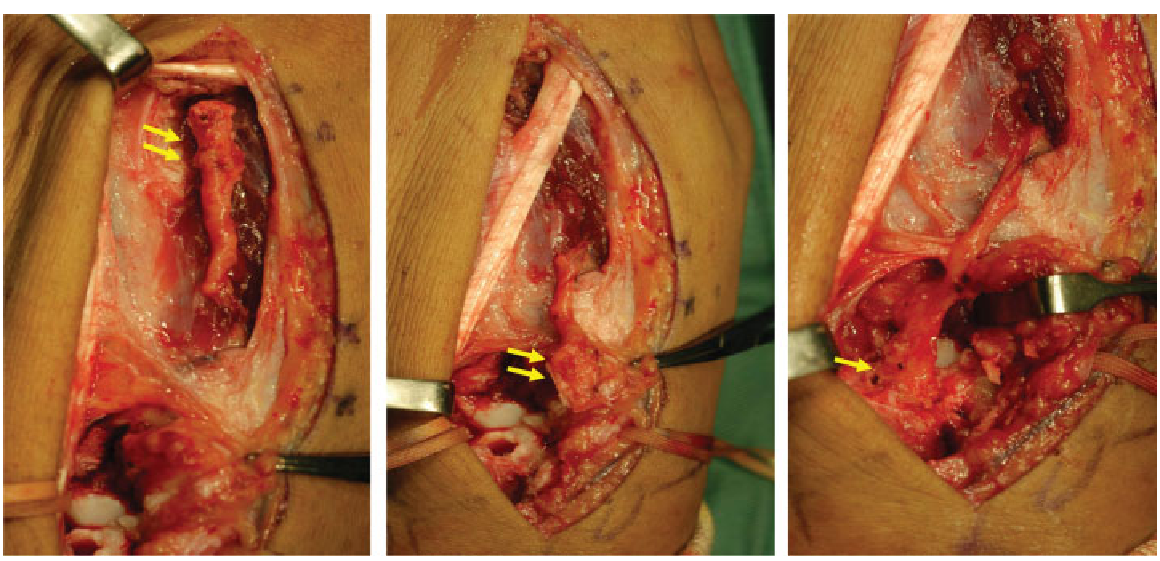

Fig. 4 The second dorsal metacarpal artery–based vascularized bone graft from the metacarpal neck harvested and transferred to the necrotic lunate. Arrows indicate the vascularized bone.

Table 1 Patient characteristics

	First and second ICR	Fourth and fifth CR	Second MC
Age	33 ± 13	38 ± 17	32 ± 11
Gender			
Male	9	6	6
Female	3	2	2
Affected side			
Right	7	3	5
Left	5	5	3
Symptom duration (mo)	17 ± 10	8 ± 6	14 ± 10
Ulnar variance (mm)	0.3 ± 1.4	0.4 ± 1.2	-0.3 ± 1.2

Abbreviations: CR, compartmental retinacular; ICR, intercompartmental retinacular; MC, metacarpal neck.

paired *t*-test, and distribution of Lichtman staging was compared using chi-square test. Each value of the CHR and RSA in the three groups was compared using analysis of variance and post hoc analysis. Values of *p* less than 0.05 were considered significant.

Results

Follow-up periods averaged 70 months. Patient characteristics were similar between the three groups (►**Table 1**). Wrist pain reduced in 27 of the 28 patients, and VAS for pain of pre- and postoperative level averaged 59 and 18, indicating significant difference ($p < 0.01$). Range of wrist flexion and extension motion improved following surgery from 87 to 117 degrees, and postoperative % ROM showed significant improvement ($p < 0.01$). Improvement of % ROM was comparable between each group of patients. Average grip strength improved postoperatively from 21 to 33 kg. Postoperative % GS increased significantly compared with the preoperative values in each group ($p < 0.01$), and these increases were comparable between the three groups (►**Table 2**). Postoperative DASH score and modified Mayo wrist score were also comparable between the three groups.

CHR had almost no change between pre- and postoperative values (0.52 and 0.53, respectively). RSA decreased once in the immediate postoperative X-rays measurement and returned to the preoperative level at the final follow-up. Fragmentation of necrotic bone healed in 7 of the 14 cases. Fragmentation at palmer aspect of the lunate was not healed. Three cases demonstrated postoperative progression of radiological staging. Surgery-related complication included migration of grafted bone, fracture in donor site, and

Table 2 Functional outcomes

	First and second ICR	Fourth and fifth CR	Second MC
VAS			
Preoperative	58 ± 12	62 ± 10	58 ± 16
Postoperative	16 ± 21[a]	20 ± 10[a]	18 ± 13[a]
% GS			
Preoperative	57 ± 14	54 ± 18	58 ± 27
Postoperative	91 ± 11[a]	82 ± 18[a]	91 ± 12[a]
ROM			
Preoperative	57 ± 16	63 ± 12	46 ± 18
Postoperative	72 ± 19[a]	77 ± 11[a]	70 ± 10[a]
Cooney score			
Postoperative	6/12	5/8	4/8
DASH			
Postoperative	2 ± 2	4 ± 3	8 ± 6

Abbreviations: CR, compartmental retinacular; DASH, Disabilities of the Arm, Shoulder and Hand; GS, grip strength; ICR, intercompartmental retinacular; MC, metacarpal neck; ROM, range of motion; VAS, visual analog scale.
[a]Significant differences between pre- and postoperative values.

breakage of pinning in one, respectively. Comparative analyses of radiological outcomes between the three donor-site grafts found no significant difference (►Table 3).

Discussion

Although there are several surgical treatment options available, vascularized bone grafting is one of the established procedures for lunate reconstruction in Kienböck disease. Daecke et al[37] reported the results of long-term follow-up on 23 patients with stages 2 and 3 disease treated with a pedicled pisiform vascularized graft. At 12-year follow-up, the mean DASH score was 15 and the mean Cooney score was 82, and 15 out of 22 patients did not experience disease progression. They concluded vascularized bone graft obtained good functional outcomes for Kienböck disease and prevented lunate collapse in the long term. Fujiwara et al[42] reported long-term outcomes of vascularized bone graft in 18 patients with stage 3 disease who were followed up for at least 10 years. A total of 11 patients underwent transplantation from the metacarpal base, and 7 had graft from the distal radius. Associated procedure of radial shortening or capitate shortening was performed in stage 3B patients. Modified Mayo wrist scores were excellent in eight patients, good in seven patients, and fair in three patients. Although CHR were not improved in stage 3A patients who underwent vascularized bone graft alone, vascularized bone grafting for stage 3 Kienböck disease demonstrated favorable long-term results.

The current analysis of functional outcomes indicated vascularized bone grafts from different donor sites demonstrated comparable results. We found significant improvement of wrist pain and the objective outcomes (range of wrist motion and grip strength) following the three donor-sites grafting. These favorable outcomes are probably due to sufficient vascular supply and mechanical construct of the current grafts. As technical pearls and pitfalls, vascular pedicle was safely elevated including the intercompartmental retinaculum and fascia of the dorsal interosseous muscle. Corticocancellous graft (a size of $10 \times 5 \times 8$ mm) with a two-sided cortical bone was harvested. It was also safe to include the periosteum with a vascular pedicle at the connection site between the graft bone and the vascular bundle. The grafted bone was inserted into the lunate as to align the cortex of grafted bone longitudinally to resist compressive force to the lunate.

Although several donor sites are available for vascularized bone grafting, we consider surgeons who know of detailed vascular anatomy around the wrist can acquire technical skill to elevate vascularized grafts from multiple donor sites. The skill can flexibly deal with variation of vascular anatomy and change of vascularity due to possible traumatic history. There is appropriate donor-site selection of vascularized bone graft for carpal bone necrosis. The surgical approach could be determined depending on the location of fragmentation of necrotic bone and associated carpal deformity. When we apply vascularized bone graft in patients with Kienböck

Table 3 Radiological outcomes

	First and second ICR	Fourth and fifth CR	Second MC
Fragmentation (healed/total)	4/7	0/3	3/4
Staging			
Preoperative			
Stage 2	2	6	0
Stage 3A	4	2	4
Stage 3B	6	0	4
Postoperative			
Stage 2	1	5	0
Stage 3A	4	3	3
Stage 3B	7	0	5
CHR			
Preoperative	0.5 ± 0.03	0.54 ± 0.02	0.52 ± 0.02
Immediate postoperative	0.51 ± 0.03	0.54 ± 0.03	0.54 ± 0.03
Final	0.52 ± 0.03	0.54 ± 0.03	0.53 ± 0.02
RSA			
Preoperative	62 ± 8	56 ± 7	60 ± 11
Immediate postoperative	52 ± 10	48 ± 6	50 ± 10
Final	59 ± 10	54 ± 8	57 ± 10

Abbreviations: CHR, carpal height ratio; CR, compartmental retinacular; ICR, intercompartmental retinacular; MC, metacarpal neck; RSA, radioscaphoid angle.

disease, location of collapse and fragmentation should be taken into account. The current procedures from the dorsal graft could not heal volar fragmentation. In the case with a fragmentation at volar aspect of the lunate, vascularized graft from the volar radius would be recommended. Dorsal fragmentation may be adequately treated by dorsal bone transplantation.

Conflict of Interest
None.

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